Reviews

Contemporary concepts in reconstructive surgery of the diaphragmatic defects

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Abstract

Concepte contemporane în chirurgia reconstructivă a defectelor diafragmatice

Defectele diafragmatice congenitale şi dobândite continuă să fie o problemă majoră în chirurgia pediatrică. În ultimii ani, tratamentul chirurgical al defectelor diafragmatice congenitale a evoluat de la o abordare urgentă la intervenții chirurgicale amânate, efectuate după stabilizarea stării copilului. Autorul descrie mai multe opinii conform cărora intervențiile chirurgicale de urgență rămân preferabile în herniile Bochdalek sau herniile diafragmatice majore asociate cu alte afecțiuni patologice: volvul gastric acut, perforația stomacului cu pneumotorax, peritonită perforativă, etc. În articol sunt descrise avantajele şi dezavantajele a diferitor aborduri deschise (thoracic, abdominal), strategiile de tratament miniinvaziv, cât şi diverse procedeie tehnice de închidere a defectelor diafragmatice. Autorul conchide, că deşi au fost înregistrate unele rezultate promițătoare în tratamentul herniilor şi eventrațiilor diafragmatice congenitale, tratamentul consensusal al acestor malformații rămâne eluziv, dovezile clinice în sprijinul mai multor modalități terapeutice fiind limitate, impunându-se necesitatea unei evaluări atente cu estimarea realistă a potențialelor riscuri.

Cuvinte cheie: defecte diafragmatice, hernie diafragmatică, eventrație diafragmatică, tratament chirurgical, grefe biologice

Abstract

Congenital and acquired diaphragmatic defects continue to be a major problem in pediatric surgery.Last years, the surgical treatment of congenital diaphragmatic defects has evolved from an urgent approach to delayed surgery after the child's condition has been stabilized. The author describes the opinion of several authors that emergency operations remain preferable in Bochdalek hernias or major diaphragmatic hernia associated with other pathological conditions: acute gastric volvulus, perforation of the stomach with pneumothorax, peritonitis, etc.
There are described the advantages and disadvantages of thoracic and abdominal approach, the miniinvasive treatment strategies and the techniques of diaphragmatic defect closure. The author concludes that although some promising results have been recorded in the treatment of diaphragmatic hernias and eventrations, the consensus treatment of these malformations remains elusive, clinical evidence supporting several therapeutic modalities being limited, requiring a careful assessment with the realistic estimation of potential risks.

Keywords: diaphragmatic defects, diaphragmatic hernias, diaphragmatic eventration, surgical treatment, biological patch

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Diaphragmatic defect correction resulting from trauma or congenital origin remains a surgical problem, a major cause of morbidity and mortality in Pediatric Surgery [68, 95].

Over the past few years, the surgical treatment of congenital diaphragmatic defect evaluated significantly from emergency operation until the delayed intervention with the elective diaphragmatic defect, made after the stabilization of the condition of the child and the cardio-respiratory functions [81, 119, 125]. Surgical intervention strategy "delayed" in association with a gentle ventilator and, occasionally, with use of ECMO support, guarantees the best results [58, 125]. Emergency surgical interventions are preferred only Bochdalek hernias or major diaphragmatic eventrations, associated with other pathologic: acute gastric volvulus, perforation of the stomach with antenatal development pneumotorax and perforative peritonitis, etc. [55].

The purpose of preoperative diaphragmatic defect is "stabilizing" the patient: acceptable oxygenation (PaO2 > 40 mmHg) and CO2 (with arterial pressure growing < 60 mmHg) pulmonary pressure (50% of the pressure < systemic) [124].

The objectives of the operations have in diaphragm defects surgery aimed at reducing herniated content with closing the defect, thus resulting in the correction of the disfunction of ventilation and lung protection [25]. In this context, the choice of the technical process depends on several factors, the size of the defect, precise anatomical details or type directly influencing its prognosis of these malformations [1, 110].

Surgical treatment of diaphragmatic defect can be done through an open thoracic or abdominal approach [127, 137], and with the miniinvasive treatment strategies [139]. In most cases (91%) is applied to an abdominal subcostal incision [25, 67, 128]. Some authors consider that a midline longitudinal laparotomy is a good approach for exposing enough of diaphragmatic defect [131]. Laparotomy offers several advantages in comparison with open thoracotomy approach through: reducing easier viscera from the thoracic cavity, the possibility of mobilizing the posterior edge of the diaphragm, intestinal rotation malformations and avoidance of musculoskeletal posttoracotomic sequelae [127].

Transtoracic appproach in diaphragmatic hernia, was promoted by Truesdale P.E. (1921) and Everett Koop and Johnson J. (1952), it was considered beneficial by the rapidity of the thoracic cavity drain, especially in children with respiratory difficulties, and through better exposure of the diaphragm, subsequently challenged Gross R.E. (1953) [137]. Some authors consider that the thoracotomic approach is the best in posttraumatic diaphragmatic hernias, laparotomy being preferred in patients with abdominal injuries [37]. The literature is described and a combined abdomino-thoracic approach to diaphragmatic hernias [120].

Miniinvasive surgical techniques, both laparoscopic [57, 60] and thoracoscopic [32, 83,108], are considered safe alternative approaches in reconstruction of the diaphragmatic defect [33]. Clinical efficiency of endoscopic techniques in the treatment of diaphragmatic defect is comparable with open surgical intervention that could be the favorite in the treatment of these pathological states [76].

Thoracoscopic approach in congenital diaphragmatic defect was used for the first time in 1995 by Cristian M.L. et al. and represents a feasible and effective option in patients with diaphragm defect [92], providing the advantage of facilitating the diagnosis and treatment of pulmonary lesions associated with [75], being useful in cases of recurrence [61]. According to some studies, the thoracoscopic approach in congenital diaphragmatic hernias has a significantly higher rate of relapses, but also surviving rate [66, 128]. Thoracoscopic method is recommended and the diaphragmatic defects acquired, because it avoids many potential difficulties existing in transabdominal approaches [65].

Morgagni hernia correction surgery is performed immediately after diagnosis, even in asymptomatic forms, due to the potentially fatal complications, such as strangulation and volvulus, intestinal obstruction, ischemia and necrosis [36, 72, 93]. It has not reached a consensus concerning the abdominal approach. Achieved through upper midline incision or upper transverse abdominal approach allows easily and control access to herniate simultaneously repairing bilateral hernias, diagnosis and correction [6].

One of the scope of surgical intervention in congenital diaphragmatic defects is the excision of the hernial sac which remains a controversial issue [4, 10, 78]. While some authors argue the necessity of its excision because of the risk of pneumomediastinum, deterioration of mediastinal structures and cardio-respiratory complications, others would maintain in situ with good results [10, 14, 82, 118].

Opinions were divided, and with regard to how the closing of the hernia defect: either by using a primary repair with sutures or applying a continuous or nonresorbable interrupted, either through the use of prosthetic material. Transabdominal approach with absorbable interrupted sutures remain the preferred option [6, 14], including with the use of laparoscopic techniques [129].

Intrapericardiale congenital hernias can be solved by simple surgical primary closure and use of prosthetic patch, in clear diagnosis to recourse to the abdominal approach. In chronic cases, when there are endorsements between liver, pericardium, heart, the thoracic approach seems more secure. It is recommended, and the questionable diagnosis, because the intrapericardial

formations, such as cysts, teratomas and others can be removed in this way [15, 55].

Surgical treatment of congenital diaphragmatic defect closure aimed at them by bringing the edges and their fixation with absorbable interrupted sutures [25,102]. Clinical practice has shown that the major-sized diaphragm defects or hemidiaphragm agenesis in reconstruction methods with the application of direct suture are less effective [84].

Using perfused muscle flaps has certain advantages in the diaphragmatic reconstruction tension free, but not in primary repair [80, 90, 122].

Simpson J.S. and Gossage J.D. (1971) in congenital diaphragmatic hernias with major dimensions, through the subcostal approaches, used a pediculate muscle flap from anterior abdominal wall, which consists of the internal oblique muscle and transverse abdominal, which was sutured stump at the edges of the defect, achieving a satisfactory closure without significant deformation of the coast or abdominal wall. According to some opinions, this technique allows large diaphragmatic defect reconstruction tension free, without a potential risk of infection [20], the risk of relapse being comparable to that of the primary reconstruction and significantly lower than when using the patch [12].

According to the communication, using only the transverse abdominal muscle is a safe and proper technique in repairing congenital diaphragmatic major defects [8]. Bianchi A. et al. (1983), in reconstruction of recurrent diaphragmatic hernias or hemidiaphragm agenesis, has proposed using the flap from m. latissimus dorsi, the main advantage being safe feeding blood vessels with perforators. Some authors recommend that combination of m. latissimus dorsi with anterior m. serratus anterior fascia for this intervention, patients being selected with caution [109, 116].

Flap of the fascia Toldt, also called Gerota fascia consisting of diaphragmatic muscle of medial remenescence, peritoneum and fascia Toldt, connective tissue retroperitoneal space, can be a way of solving the major diaphragm defects. [34, 94].

Implantation of autologous tissue is quite complicated and invasive, requiring a long time with a high risk for bleeding, necrosis and other severe complications [138].

In major diaphragmatic defects, multiple authors indicate the use of bioprotetical patches, there is controversy regarding the type of material (or synthetic), expansion or non-resorbable, which depend directly on the results of treatment. In the literature are offered several types of prosthetic materials, without being identified as ideal [13].

Currently, the use of synthetic patch sites is the method of choice in the diaphragm defects reconstruction of major dimensions [87]. For the first time, diaphragmatic nylon patch was used experimentally by Adler and R.H. and FirmeC.N in 1957.Subsequently to this they have been tested on animals and other synthetic materials, including: Teflon by Harrison J. (1957), Ivalon by Cooley J.C. et al., (1957), Dacron by Dalton M.L. et al., (1966).

Currently they proposed several prosthetic synthetic materials in surgical treatment of diaphragmatic defect, their choice being random. The most common absorbable prosthetic materials used in reconstructive surgery, including diaphragmatic, are polypropylene (Brenda), polytetrafluoroethylene (Gore-Tex), expanded polytetrafluoroethylene (composite mesh with two faces), and place of polyethylene terephthalate (Dacron) [47, 62, 112].

Polytetrafluoroethylene is the most common biosynthetic material used in reconstructive surgery (81%) [132] including diaphragmatic [13]. This polymer formed by nature inert monofilament, produces an unstressed inflammatory response, it does not integrate the diaphragmatic tissue but not being elastic, does not ensure adequate diaphragmatic movements [38].

Synthetic patches of this material do not grow with the patient, repair processes are determined by the growing edge of tissue that can ensure diaphragmatic scope and its adaptation. If these processes do not occur, the patch as child rearing, can ward off the chest wall or edge with the development of recurrence, or chest wall may choose the synthetic material, patch deformation, causing chest wall [105].

Although the synthetic prostheses materials are durable, with angiogenesis properties can be easily modeled after the defect requiring diaphragmatic dissection and mobilization of tissues and minimum time of preparation, they remain in situ for life and constitute a microbial colonization potential, instead of requiring review at certain time periods [16,127].

For over three decades experience of use of synthetic patch showed that the main disadvantage of the method is increased recurrence rate, which can reach up to 50% of cases [86, 121, 126].

To minimize the risk of recurrence in diaphragm defects must be taken into account different aspects: the type and shape of the implant, suture material used, surgical technique, the patient type and comorbidities the dimensions of the diaphragmatic defect [121].

Recurrences can be bimodal, early in the first few months after surgery, and late that develops a few years later. Early recurrences are determined, most likely adhesions, inadequate or scar tissue it in large defects, with small portions of muscle.

Synthetic implants tend to decrease with diaphragmatic scarring, which leads to the development of late recurences in rising child requiring technical processes of reconstruction [127]. Some authors, in order to enable the extension in time, suggested fitting synthetic net in the shape of a Double Cone fixed

(double-sided) [77]. It was described and the use of synthetic patch used at all combined with two faces, made of Gore-Tex, on the one hand Marlex [104]. Regarding the surgical technique, several authors emphasize how the application of sutures and fixation of the prosthetic patches, eventually crossing the sutures around the ribs with intercostal muscles, involvement being used, typically, thread that is not absorbed [35, 83, 107].

While initially a pediculate muscle flaps and use of prosthetic synthetic absorbable materials seemed a good solution, in many studies, there has been an increased incidence of late complications, including: intestinal obstructions, need splenectomy, of the chest wall and abdominal deformities [97, 127]. According to some studies, propylene is causing most of the grips, their formation being related to pore size. The macroporous polypropylene mesh facilitates adhesion formation rather than the expanded polytetrafluoroethylene microporous [45, 91]. In children operate for major diaphragm defects, scoliosis was found in 4%-50% of cases and in 14% deformity of pectus-80%, no statistical difference observed between these two ways of surgical correction [90, 106].

The use of biological materials in the repair of congenital and acquired diaphragmatic defects is limited to small series and case reports [5]. Janes R.M. (1931) proposed the use of fascia lata graft in the treatment of post-traumatic diaphragmatic hernia, and in 1968 the use of this graft was reported in the surgical treatment of hiatal hernia by transthoracic approach, this method remaining current at present [19], including in the treatment of recurrent congenital diaphragmatic hernias [121]. Unique cases of use of human dura mater grafts, fascia lata and bovine peritoneum in diaphragmatic defects are reported [11, 50, 77, 103].

At present, considerable efforts are being made to develop alternative ways of closing both, congenital and acquired diaphragmatic defects [35, 113]. Progress in stem cell biology and tissue engineering has led to the creation of more bioengineering tissues that can be incorporated into host tissues by regenerating natural tissues with the ability to grow with the patient [28, 56]. The decellularization process allows the removal of resistant cells from donor tissues by special technologies, thus obtaining an extracellular three-dimensional matrix while preserving the native biochemical architecture including the maintenance of microvascular networks, which can be reclaimed with new progenitor or composite cells. The drastic reduction in DNA amount, significant cell depletion while preserving several properties of the treated tissue is a crucial outcome in decelularization methods, with the aim of avoiding any immune rejection of the graft [74, 98].

In the past decades, several biological grafts have been created, some of which are approved in clinical practice, including human cadaveric dermatitis, submucosa of the pig's small intestine, bovine pericardium. These materials have successfully demonstrated the ability to support human tissue repair [18]. There have also been described several acellular biological grafts as an option in the reconstruction of diaphragmatic defects [127], among which Alloderm [23], Surgisis [48], Permacol [86].

The human acellular dermal matrix is an allogeneic material obtained from human cadaveric skin (AlloDerm; LifeCell Corporation, Branchburg, NJ) with the special removal of cellular components of the dermis and epidermis. Several studies have found that the Alloderm graft exhibits biomechanical properties comparable to those of the abdominal wall or synthetic mesh fascia, and its early revascularization increases resistance to infection and contamination. The advantages of this material against synthetic prosthetic materials are: development of a minimal adhesion process, remodeling with autologous vascular tissue and resistance to infections [9].

Surgisis (SIS, Cook Biotech Inc., Cook Deutschland GmbH, Monchengladbach) is an extracellular matrix of porcine acellular intestinal submucosa, which is a type 1 collagen structure with active growth factors which after implantation undergoes degradation processes and remodeling and collagen replacement of the host [38].

Permacol is an acellular chemically-bonded dermal derived porcelain collagen material that produces an unprompted inflammatory response consistent with the normal wound healing process that allows for good incorporation. Welding of lisin and hydroxylisin residues from Permacol's collagen fibers gives the material greater resistance to collagenation and higher durability, and is considered by some authors to be a safe alternative to synthetic nets [86, 102].

In order to overcome the disadvantages and limitations of known prosthetic materials and to create optimal materials for closing the diaphragmatic defects, the feasibility of the use of cross linked porous collagen grafts obtained by tissue engineering techniques and composite or hybrid meshes resulting from the combination of several prosthetic materials, including polyester/collagen grafts [132], poly (ε-caprolactone)/collagen [138], a combination of several prosthetic materials, including polyester/Vicryl/ Colagen [21]. The results obtained are at the dizerate stage.

In severe forms of congenital diaphragmatic hernia, closure of the abdominal wall after the reconstruction of the diaphragmatic defect can be quite difficult due to a potential inconsistency between the volume of the viscera, which must be reduced, and the size of the abdomen, insufficiently developed [68]. Loss of pulmonary compliance may be due to an internal defect of the lung parenchyma or restricted mobility of the tho-

racic and abdominal cavity. Restrictions induced by these two sources can cause significant reduction in respiratory volume, causing worsening of adequate ventilation capacity of the diaphragmatic hernia. In this context, some authors hypothesized that applying a silo bag to the abdominal wall would greatly reduce the decline in abdominal wall compliance, associated with the primary closure of the abdominal wall after repairing the diaphragmatic defect [100].

With regard to abdominal wall enlargement techniques, there are reports of delayed closure of the abdomen after reconstructive interventions in children with congenital diaphragmatic defects [68, 111]. The phenomenon can be determined by the potential consequences of abdominal cavity reduction after the diaphragmatic defect closure, namely the sudden increase in intra-abdominal pressure and the development of compartment syndrome [81].

Chylothorax is a potentially severe complication after diaphragmatic hernia reconstruction, with an incidence of 5.5% -28% [73, 85]. This complication generates nutritional deficiency, hypoproteinemia, electrolyte disturbances and compromises immunity [69]. Although the exact etiology of chylothorax in the diaphragmatic hernia remains unknown, several theories have been proposed, including: lymphatic vessels dividing into hernia sac, direct traumatic lesion of diaphragmatic lymphatic vessels, and pressure phenomenon of visceral lymphomas resulting in small rupture of the thoracic canal [85]. Effective management of this complication continues to be a challenge, the initial treatment consisting of tube thoracostomy and total parenteral nutrition. The effectiveness of using a continuous perfusion with octreotide, as adjunctive therapy, remains controversial. The surgical treatment of chylothorax is indicated after a period of 1-3 weeks of conservative therapeutic measures, or in cases where more than 15 ml/kg of fluid is eliminated through the thoracic drainage [39, 69]. Numerous aspects of surgical treatment in congenital diaphragmatic defects are still questionable, especially the criteria for selecting surgical techniques [125] and the increased recurrence rate, which varies between 3% and 50% [99]. These patients frequently complain of vomiting, intestinal obstruction and abdominal pain (58%) or pulmonary pain (17%) [49].

Indications for surgical treatment in diaphragmatic events are: pulmonary compression with tachypnea without any improvement after conservative treatment, cardiac compression with arrhythmias, two or more recurrent pneumonia, severe life-threatening pneumonia which endangers the patient's life with failure to disconnect from mechanical ventilation, respiratory distress associated with paradoxical diaphragm movements [71, 135]. Surgical treatment of diaphragmatic eventration in children is indicated not only in symptomatic patients [40], but also to seemingly asymptomatic patients with major disorders of ipsilateral pulmonary function, found in the ventilation and infusion assessment [134, 135]. Diaphragmatic eventration associated with spontaneous diaphragm rupture [43], intestinal obstruction [3], symptomatic gastric volvulus, or suspected perforations are surgical emergencies where the most frequent recurrence to a subcostal or transversal abdominal incision. This approach makes it possible not only diaphragm bladder, but also anterior gastric fixation by gastropexia or gastroductomy [79, 117].

Regardless of the congenital or acquired origin, the classic thoracic approach through an incision in the intercostal space 7 or 8 is considered the optimal option in the exposure of diaphragmatic eventration [7]. The aim of surgical correction is to restore the diaphragm's topographic location, to provide the lung with a larger volume of expansion, and to restore satisfactory ventilation [41, 135]. Immobilization of the diaphragm through the envelope contributes to the reduction of the paradoxical movement and the contralateral movement of the mediastinum organs. The thoracic approach is the only possible placement of the right-handed eventration, and in the left-hand position in the central and anterior regions an abdominal approach can be used [124].

The open transabdominal approach provides access to both sides of the diaphragm and does not require selective ventilation, and laparotomy is a less morbid incision than thoracotomy [41]. The correction of diaphragmatic eventrations incidence using miniinvasive techniques, including laparoscopy [51, 133] and thoracoscopy [29, 52, 59, 63] are an acceptable alternative and along with assisted video surgeries are safe methods with satisfactory results in repairing the diaphragmatic event.

Several surgical techniques have been proposed to repair the diaphragmatic eventration, including excision and suture, diaphragmatic bladder and prosthetic patches [7]. The most commonly used technique in diaphragmatic eventration and paralysis is diaphragm epithelium [71, 101, 135], which aims to reduce dysfunctional caudal diaphragm excursion during inspiration [7]. For the first time application of this procedure to adults was described in 1923 by Morrison J.N.W. [41], although it was proposed by Wood in 1916 [71]. In children, the first diaphragmatic bladder was carried out in 1947 by Bisgard to a child with respiratory insufficiency [123].

Several intact or sectioned diaphragm processes are described [31, 130]. The envelope "in the overcoat" provides for the return of the diaphragmatic dome into tension, making a flame-shaped front flap directed towards the pleural cavity maintained at the base by a row of U-shaped non-resorbable sutures. Then the re-

tained portion is folded in front, anterior or posterior after is sutured with diaphragm with interrupted sutures, thus creating three layers superimposed on the thin part of the diaphragm [71]. The inverse inversion folding procedure involves suturing tight diaphragm edges by positioning the excess length to the peritoneal cavity. The first non-resorbable wire in surget is applied to close the depression at the periphery of the diaphragm. Subsequently, a second surget is applied [29, 88].

The central nesting technique consists in the application of several linear rows of horizontal non-resorbable sutures through the weakened part of the diaphragm. With sutures they are tightened in folds and weak tissues, creating a tense diaphragmatic surface [96].

The diaphragmatic enveloping techniques used have proven to be safe, simple and appropriate in the surgical correction of diaphragmatic eventrations incidence in children with good outcomes. They allow the reduction of most preoperative symptoms immediately after surgery and amelioration of pulmonary function [71].

Postoperative complications of diaphragmatic bladder include: atelectasis, pneumonia, pleural effusion, abdominal compartment syndrome, and spleen lesions, usually in the abdominal approach [44].

There are also unique communications for the successful use of Gore-Tex synthetic meshes in the correction of diaphragmatic eventrations [24, 53].

Despite the improvement in the survival rate and the change of the basic management paradigms, the consensual treatment of congenital diaphragmatic defects remains elusive, clinical evidence in support of several therapeutic modalities being limited. Although advances in the treatment of congenital diaphragmatic defects are quite promising, the results of a new treatment approach require a careful assessment with a realistic estimate of potential risks before the recommendation in practice [127].

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